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Original Article

The Impact of a Training Intervention on Detection of Patient-Ventilator Asynchronies in Nursing Students

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Abstract. *Background and aim of the work:* Patient-ventilator asynchronies (PVA) are associated to negative outcomes for patients: increased respiratory work, mechanical ventilation time and ICU length of stay, and mortality. Some studies described the positive impact of a training intervention on the knowledge and attitudes of nurses in detecting PVA. The aim of this study was to evaluate the efficacy of a training intervention focused on detection of PVA. *Methods:* A before-after design on a single group of nursing students (University "L. Vanvitelli" in Naples) was used. The training intervention about detection of the correct respiratory waveform through graphic monitoring was conducted in a single edition live course of 2 hours, for 25 participants. Measurements of correct detection of PVA through specific competency assessment tool (closed-ended question) were performed before (T0), immediately after (T1) and at 1 month (T2) from the training intervention between January and February 2020. *Results:* 19 Nurse students completed the training. A total of 50 questionnaires were distributed (T0; n=19; T1; n=19; T2; n=12). PVA were correctly detected in 67.5% (77) of cases. Statistically significant difference There were differences in trainees' performance between T0 and T1 [77,2% (CI 95%: 68,7% - 85,8%; p=0.001)] and between T0 and T2 [75% (CI 95%: 65,3% - 84,7%; p=0.001]. No significant difference was recorded between T1 and T2 (p=0.83). *Conclusions:* Nursing students increased their performance on analysis of the graphic monitoring of the respiratory waveforms and detection of asynchronies after a basic training intervention. These skills were retained after 1 month. (www.actabiomedica.it)

Keywords: nurse students, education, training, ventilator waveform, asynchrony

Introduction

About a third of intensive care unit (ICU) patients require the use of mechanical ventilation, a rescue treatment necessary for the vital support of critically ill patients with severe respiratory failure (1). Mechanical ventilation (MV) replaces the lung function to allow the primary problem underlying respiratory failure to be resolved (2). MV is based on the interaction between patient and machine. This interaction is an expression of two functions controls, that is, the ventilator controlled by the doctor and the respiratory muscles controlled by the patient (3).

Inadequate interaction between the machine and the patient generates asynchrony (4), a phenomenon occurring in a range 2%-50% of adult ICU patients (5), while in paediatric ICU patients is 27% (6).

The causes of patient-ventilator asynchronies (PAV) can be attributed to an inadequate or excessive level of sedation (5, 7, 8), or an inappropriate setting of the ventilator parameters (5, 9). Several negative outcomes for patients may be attributable to asynchronies, including increased respiratory work (10), prolonged of mechanical ventilation duration time, increased ICU length of stay and mortality (11), prolonged respiratory weaning (12) and impaired gas exchange (13). Moreover, authors report also: patient discomfort and cognitive dysfunction (7), increased dyspnea (11), impaired sleep quality (7) and possible lung injury or diaphragmatic damage (3, 7, 14).

A proposed ventilation mode for the reduction of asynchrony is the Neurally Adjusted Ventilatory Assist (NAVA) (15). NAVA is linked to the positioning of an esophageal catheter that detects the electric activity of the diaphragmatic muscle through a series of electrodes (16, 17). However, this method is still sporadically used in daily clinical practice and mostly used in research (14). A non-invasive alternative for the prevention and resolution of PAV is represented by the analysis of respiratory waveform on the ventilator display by healthcare professionals, (18, 19), aimed to identify some details in the morphology of the curve or changes of the respiratory cycle (9, 19).

During the pandemic period, mechanical ventilation has been a fundamental treatment for critically ill patients (20). Moreover, many new-graduate nurses have been quickly hired in hospitals and assigned in COVID-19 areas, included ICUs (21). This condition, characterized by the need of expertise and skills in the mechanical ventilation management, has raised the awareness that the monitoring of ventilator waveforms is still not included in the bachelor's degree of nurses studies.

However, research showed that a properly trained nurse is as accurate as a doctor in detecting patient-ventilator asynchronies (22). Some studies have described the positive impact of a training intervention on the knowledge and attitudes of nurses in detecting asynchronies (18, 23).

Moreover, international experiences highlighted that nursing students have good clinical competence, but they have the perception of being deficient in the evaluation and during the monitoring phase (24). However, to date there are no published studies on the effect of interventions on PAV detection in nurse students.

Aims

The purposes of this study were to evaluate the impact of a training intervention on PAV detection in nurse students in terms of acquired knowledge and retention of skills one month after the education program.

Methods

Study design and sample

A before-after study was conducted among students of the last year of the bachelor's degree course in Nursing Sciences (University "L. Vanvitelli" in Naples branch of Maddaloni [CE]). All nursing students who followed the course on "intensive care nursing" were included in the study; no exclusion criteria were applied.

Study endpoints

The primary endpoint was to record the level of acquisition of the skills on identification of PAV after an ad hoc training intervention. The secondary endpoint of the study was to record the level of knowledge retention 30 days after the training intervention.

Study phases

The study was composed by 4 phases during the period between January 2020 and February 2020: (1) Assessment of pre-training intervention skills; (2) Implementation of the training intervention; (3) Evaluation of the skills acquired post-training; (4) Follow-up. The first 3 phases were implemented on the same study day and phase 4 was conducted after 30 days. During the phases 1, 3 and 4 the *"competence assessment tool on patient-ventilator asynchrony"* was used, as described below.

Phases 1

Data collected in the pre-intervention phase provided information on the baseline knowledge relating to the detection of respiratory waveforms. In this phase, nine didactic slides representing the ventilator waveforms were showed (6 representing asynchronous patients, and 3 non-asynchronous patients). Students were asked to analyze the images according to their basic knowledge but responding through the six steps of a ventilator waveform interpretation method previously validated (25) and finally to discriminate if a PAV was present or not (but without the request to guess the type of asynchrony).

Phases 2

In phase 2 the training intervention was implemented (see details in next section).

Phases 3

Once the training intervention was finished, the same slides showed in the pre-training phase were proposed in a different order.

Phases 4

The follow up phase took place 30 days after the training intervention. The students who participated in the training event were contacted and asked to evaluate the same images proposed in a different slide sequence from the first 2 sequences but requiring following the same 6-steps assessment method for the interpretation. In all phases of the study, the missing answers were considered incorrect, while answers were considered correct if they reflected a congruence between the answers provided by the proposed method and the answer provided by the trainee.

Training intervention

The training intervention was a seminar focused on the detection of the correct respiratory waveform through graphic monitoring interpretation. The single edition seminar lasted 2 hours for 25 participants. The teaching methodology used traditional lectures with the projection of didactic slides about respiratory waveforms. The training was conducted by a highly skilled intensive care nurse, a scientific manager, and a tutor in nursing courses on the principles of monitoring in mechanical ventilation.

The concepts of mechanical ventilation were theoretically addressed and a method of analysis of the respiratory waveforms was proposed to facilitate the healthcare professionals in the correct interpretation of the ventilator waveforms (18, 25). The analysis method follows the physiological cycle of respiration and consists of 6 steps: (1) Identify the pressure/time and flow/time waveforms; (2) Identify the inspiratory and expiratory phase; (3) Check the activation of the inspiratory muscles or the activation of the trigger; (4) Evaluate how the pressure changes in the inspiratory phase; (5) Detect the possible activation of the expiratory muscles; (6) Observe the expiratory phase (Bulleri & Fusi, 2015). Determining the phase (inspiratory and expiratory) of the respiratory cycle provides the data relating to the patient's inspiratory efforts, characterized by an increase in trans-diaphragmatic pressure and / or electrical activity of the diaphragm (26, 27). A weak or absent activation of the inspiratory muscles could generate asynchrony (12). By observing the modification of the pressure-time diagram, some of the most frequent asynchronies can be determined (28). The early activation of the expiratory muscles due to the increase in airway pressure may also indicate suboptimal synchrony; finally, monitoring the expiratory flow returning to baseline is also crucial (25).

Competence assessment tool on patient-ventilator asynchrony and method of administration

An ad hoc multiple-choice test consisting of 19 items composed by three parts was carried out for data collection: (1) description of the sample, (2) clinical experience and (3) images and ventilator waveforms analysis. This method was previously employed with successful experiences described in the literature. (23, 29).

The data collected included: student's demographic data (gender, age, nationality), clinical experiences in terms of internship experiences (intensive care unit, operating room, emergency department and high dependency unit), external tutoring on mechanical ventilation (e.g., assisting/managing invasive or non-invasive intubation) and finally if she/he had ever dealt with the topic of asynchrony in a clinical environment.

After having finished the training session in the classroom, the test for post-intervention evaluation was distributed to all students who had concluded the training. Each student had the same time to answer the test (7min/Item). For each image showed in the slides, students were asked to interpret the ventilator waveforms. Furthermore, for each image, to every student was asked "if the image corresponded to an asynchrony" (yes or no), using the six steps learnt during the training session.

Data analysis

Data analysis was carried out with the scikit-learn library of the Python language. A random alphanumeric code was attributed to the test results and subsequently loaded onto the Microsoft Excel worksheet. The answers to the questions and the phases of the study 1-pre-intervention (T0), 3-post-intervention (T1) and 4-follow-up (T2) were considered as fixed effects, the subjects exposed to detection as random effect. An inter-rater test was used to measure the reliability of the assessment test in the group of participants using K-Fleiss on T0 and T1 between students and nurses (30). For measure of inter-rater agreement, by K-Fleiss, we asked to 5 critical expert nurses (second observer) to interpret the same images show to nurse students. A K value between 0.01 and 0.20 showed a slight agreement; fair agreement between 0.21 and 0.40; moderate agreement between 0.41 and 0.60; substantial between 0.61 and 0.80; almost perfect agreement for a range between 0.81 and 1 (31). Group comparisons were made with the Tukey test and the one-way Anova test. The statistical significance level was set for p = 0.05 and 95% confidence interval.

Ethical aspects

According to local policies, the ethics committee approval was not requested, because no evaluation / procedure was performed on patients. Participation took place on a voluntary basis and subject to the participant consent to the processing of the data collected in the evaluation tests. The data were analyzed in aggregate form guaranteeing privacy according to Legislative Decree 30 June 2003, n. 196 art. 13. The data were processed following the indications of art.13 and 14 of the General Data Protection Regulation - EU Reg. N ° 2016/679.

Results

Among 25 senior students who make up the last year of the bachelor's degree course, 19 (76%) students attended and concluded the training event. 6 (24%) were absent from the event, while 12 (48%) students were included in the follow-up. The remaining 7 were lost due to lack of response. The sample was represented by mainly female students (N. 16, 84.2%) with an average age of 22.4 (SD ± 2.3, range 21.37-23.43). Other details on the participants are provided in Table 1. Figure 1 Flow chart and study phases.

94.7% (N. 18) of the participants did not follow seminars or external didactic activities related to mechanical ventilation, but only 5.3% (N. 1) dealt with the topic of asynchronies in the clinical setting and the remaining. The positioning of a face mask for non-invasive ventilation was a commonly known technique (N. 13; 68.4%), unlike the positioning (N.5; 26.3%), or managing of an oro-tracheal tube (N. 3; 15,8%).

A total of 50 questionnaires were distributed, 19 in the 1-pre-intervention phase (T0), 19 in the 3-post-intervention phase (T1), and 12 in the 4-follow-up phase (T2), for a total of 513 responses inherent the detection of respiratory waveforms. Only 41.5% of the ventilator waveforms presented during test

Table 1 - Characteristics of the Sample

Variable	n	%
Gender		
Male	3	15,8
Female	16	84,2
Age (Years)		
20-21	8	42,1
22-23	8	42,1
≥ 24	3	15,8
Internship Experiences		
Intensive Care Unit	4	21,1
High Dependency Unit	3	15,8
Operating Room	8	42,1
Emergency Department	5	26,3

Note. there is more than one answer for the internship experience, n=19 (100%).

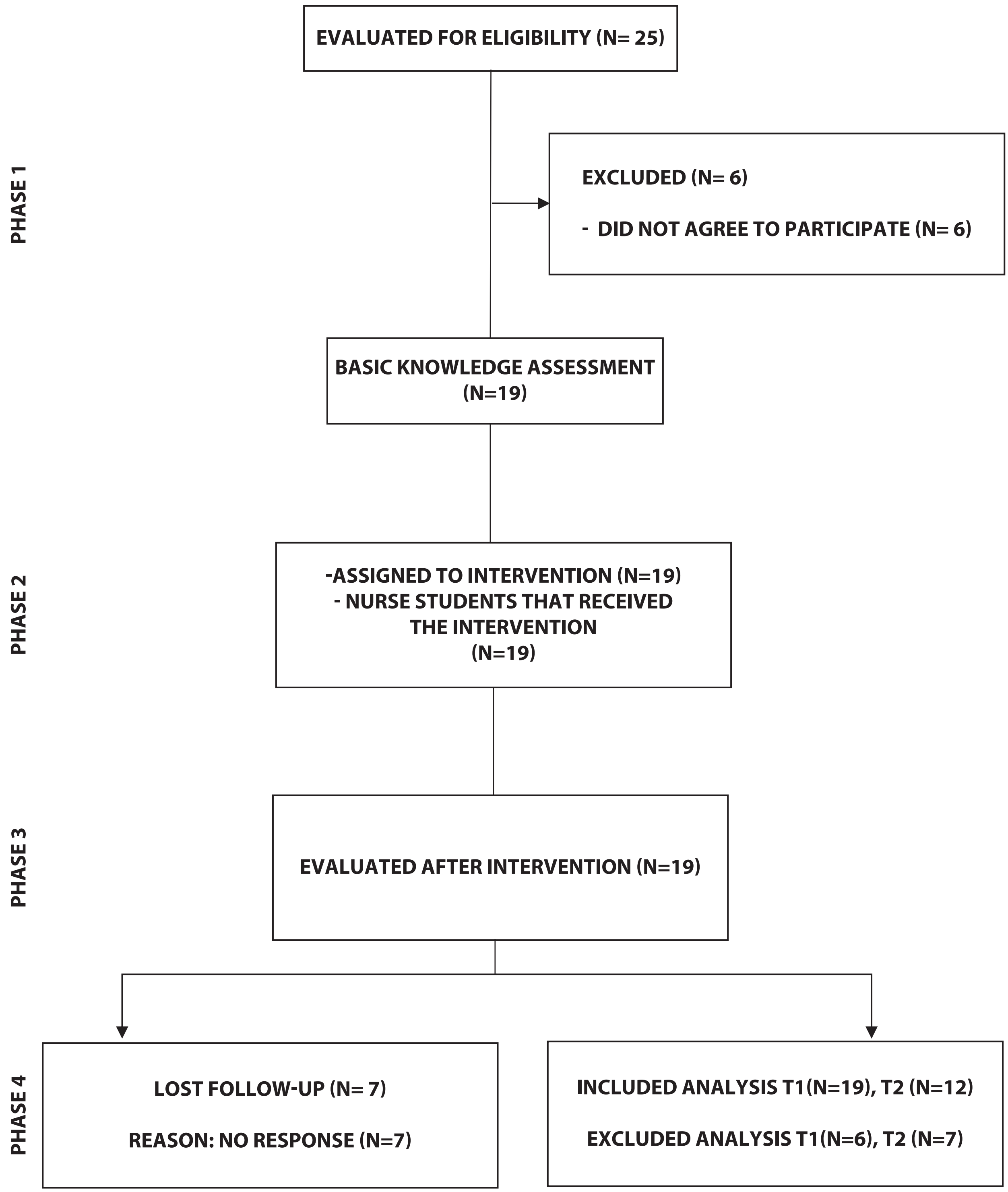

Figure 1. Flow chart and study phases

administrations were correctly identified by the students. The result of the reliability of the inter-rater assessment test obtained for T0 between nursing students and nurses was sufficient (K-Fleiss = 0.21); a similar result was found for T1 inside the same comparison (K-Fleiss = 0.25).

Pre-intervention

Before the training intervention, none of the nursing students was able to correctly identify the projected waveforms.

Post-intervention

After the training intervention, the percentage of correct answers was 77.2%. Asynchronies were correctly detected in 67.5% (N. 77) of cases; 10.5% (N. 2) of the students identified at least 3 out of 6 PAV; 78.9% (N. 15) identified at least 4 PAV, while 5.3% (N. 1) achieved to detect 5 PAV; the same percentage was reached in the detection of 6 out of 6 PAVs. By classifying them by type, all students were able to recognize the double trigger, the ineffective effort in 94.7% (N. 18), the early cycling in 89.5% (N. 17), the self-cycling in 73.7% (N. 14), while delayed cycling was only detected in 31.6% (N. 6) and flow asynchrony in 15.8% (N. 3).

Follow-up

One month after the training intervention, the exact answers provided by the students were 81 out of 108 in total (75%). The correct detection of PAV was in 49 responses out of 72 available (68.1%). 50% (N. 6) of the students at the follow-up were able to recognize at least 5 out of 6 PAV, 25% (N. 3) recognized 4 out of 6, 16.7% (N. 2) identified 3 out of 6, and finally 8.3% (N.1) detected at least one PAV out of 6. In the breakdown by type of PAV, all the students were able to recognize the ineffective effort, the early cycling in 91.7% (N. 11), the double trigger in 83.3% (N. 10), flow asynchrony in 50% (N. 6), delayed cycling in 50% (N. 6) and self-cycling in 33.3% (N. 4).

There was a statistically significant difference between the pre-intervention and the post-intervention phases (p = 0.001) and in the comparison of pre-intervention and follow-up phases (p = 0.001) (Table 2). The results obtained from the comparison between post-intervention and follow-up phases showed some non-significant differences in the average of the correct answers (p = 0.83).

The result of the linear regression for the one-way Anova test in the three different detection phases (pre-intervention, post-intervention and follow-up) indicates the distribution of the results in the post-intervention and follow-up surveys–up (Figure 2).

Discussion

The main results of this study can be summarized as follows: nursing students that do not have basic

Table 2. Multiple Comparison of Means

Groups	Meandiff	IC	P-Value
Pre-intervention (T0) Vs Post-intervention (T1)	77.2	68,7 - 85,8	0,001
Pre-intervention (T0) Vs Follow-up (T2)	75.0	65,3 - 84,7	0,001
Post-intervention (T1) Vs Follow-up (T2)	-2.2	-11,9 - 7,5	0,83

Note. IC = Interval Confidence; (P<0.05)

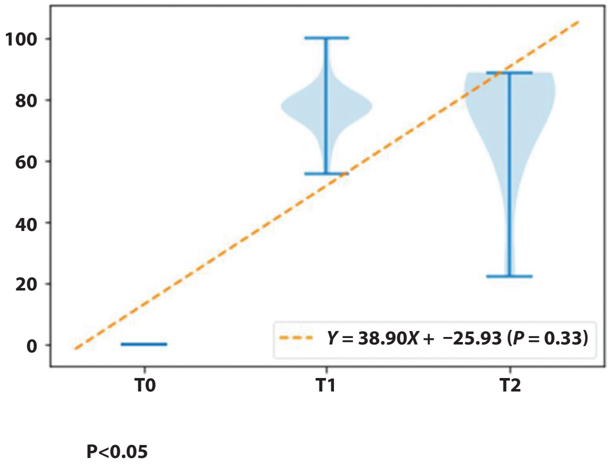

Figure 2. Linear Regression ANOVA

knowledge on PAV were able to recognize common asynchronies after a systematic training intervention, with retention of skills one month after the training.

For healthcare professionals, the ability to detect an asynchrony passes from a correct interpretation of the respiratory waveform (18). Specifically, the analysis of the ventilator waveforms occurs by visually detecting changes in the standard waveform or in the alteration of inspiratory and expiratory time (9, 19).

The basic nursing training does not provide for the acquisition of this knowledge, but is associated with medical training (22), for this reason the results of the pre-intervention are in line with the results expected by study planning, even if all the students participating in this study had attended the training course relating to "nursing in the intensive care unit setting".

Several investigations on the impact of a training intervention on specific topics not foreseen in the bachelor's degree nursing course, have shown that the knowledges and perceptions of the pre-training intervention phases are level (32, 33).

The phenomenon of PAV is of complex management even for highly trained nurses and doctors. In fact, in a study conducted in Italy, important knowledge deficiencies were found before the training intervention (23). Another study conducted in Canada on nursing students showed how a complex topic can be learned by a nursing student, reducing the anxiety of learning, promoting a considerable and positive change in the attitude towards learning (34).

The results of this study promote the expansion and strengthening of the student's knowledge in the field of monitoring of respiratory waveforms. Heidari & Norouzadeh in 2015, observed that the learning domains on assessment and monitoring in nursing students are rather lacking, attributing this result to the increase in clinical experience, the more formal interactions with other nurses and the evaluation by nursing supervisors in the workplace (24). This effect did not appear in our study as only 5.3% of the students dealt with the topic, with a clinical tutor during internships. In fact, the real increase in knowledge about the phenomenon in the group of students occurred after the training intervention ($p = 0.001$). This result is similar to that obtained after nurses participated in a training course on detecting PAVs (23). A somehow different baseline skillset was found in our study among the students before receiving the training intervention and the same difference maintained after one month.

Ideally the results obtained in studies involving revaluation should be based on information that includes complete follow-up (35). A long interval over time (e.g., 4-130 months) is chosen in the case of evaluation of clinical outcomes (36). Normally the recommended time interval in training interventions studies is about 15 days, as too short intervals could cause problems related to the increase in the reliability coefficients and students could remember the answers given previously (37). The follow-up reassessment was performed after 30 days as the level of retention of the acquisition of competence on the detection of asynchronies was a non-clinical outcome.

From the analysis of the data, there are no statistically significant differences between the preparation of the group in the post-intervention (T1) and in the follow-up (T2) ($p = 0.83$) (table 2) this result could be attributed to the students lost to the follow-up and the generated bias. Therefore, it is not possible to determine whether the differences between student preparation levels between T1 and T2 [132 (77.2%) vs 81 (75); $p = 0.83$] is real or attributable to the case.

Although in the study of Fusi and colleagues (23), the sample under study was composed of intensive care nurses who in the follow-up period may have continued to detect PAV having been in contact daily with the respiratory waveforms displayed on the monitor. Unlikely, the nursing students who (in that month) performed only theoretical teaching activities, thus failing to be able to compare the two results but provided an overview of the changes among groups that receive the same intervention (38). In fact, Fusi and colleagues found that a properly trained nurse increases his skills in detecting PAV; the same result emerged in the present study, highlighting that even a nursing student, if properly trained, increases his competence towards detecting PAV (T0 Vs T1, $p < 0.001$). Ramírez et al., in 2019 found that a health worker with more than 100 hours training in the specific topic of respiratory waveforms showed higher diagnostic accuracy than professionals who have not followed the same hours of training [OR = 2.28, (1.29-4.03); 95% CI; $p = 0.005$] (39).

This research showed the positive impact of a training intervention on specific topics not foreseen in the bachelor's degrees in nursing science. Based on this result, training integrations can be proposed with the aim to prepare the "future nurses" to quickly evolve their basic skills into advanced skills.

This study had several limitations. The low sample size is the main limit. Moreover, the single center characteristic did not allow the generalization of the results. Finally, the intervention itself in the study, represented by a seminar of only 2 hours, could constitute a limit in the learning of an advanced skill as the interpretation of the ventilator waveform.

Conclusions

The nursing students showed good performance in the analysis of the graphic monitoring of the respiratory waveforms, but the full acquisition of the competence is linked to a longer and specific training process intrinsically linked to clinical practice (39). Nonetheless, we could hypothesize that a slightly longer education programme about the detecting of PAV could enhance the future neo-graduate competence portfolio, becoming a mean to accelerate the process of integration of the newly hired nurses in the intensive care units.

This study had several limitations. The low sample size is the main limit. Moreover, the single centre characteristic did not allow the generalization of the results. Finally, the intervention itself in the study, represented by a seminar of only 2 hours, could constitute a limit in the learning of an advanced skill such as the interpretation of the ventilator waveform. Lastly, the presence of control groups (both no training and self-study through handbook interventions) could have enhanced the design of this research.

Therefore, the results of this study call for randomized trials with longer follow-up periods to monitor the PAV detection skills acquisition and maintenance among the post-graduate nurses beginning to work in intensive care units.

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Conflicts of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

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